



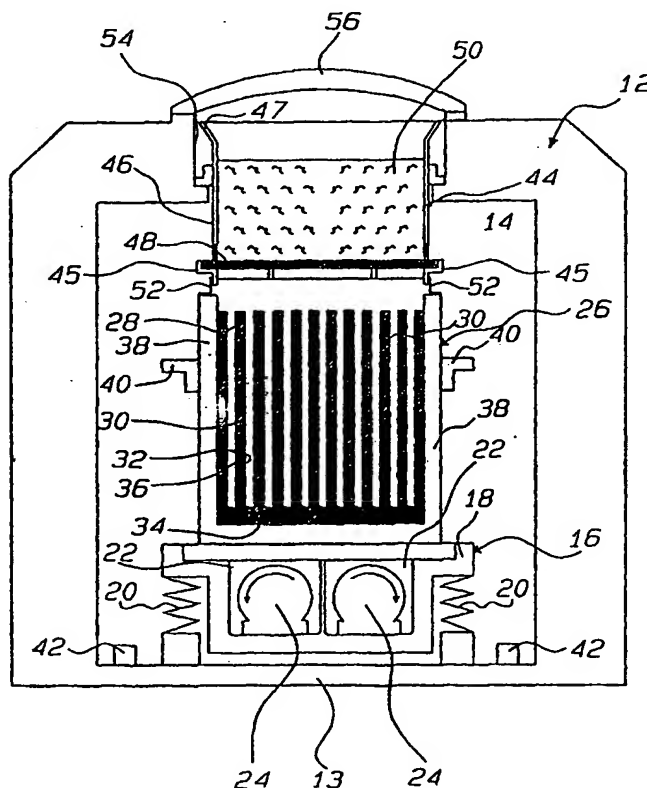
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(54) Title: METHOD AND APPARATUS FOR THE MANUFACTURE OF SLABS OF STONE MATERIAL

(57) Abstract

A starting mix is prepared, consisting of a granulate with controlled particle size and of a cementitious binder or one based on a hardenable resin, atmospheric mixing being carried out, after which the mix is fed in free fall conditions and under vacuum to a formwork (26) consisting of a plurality of moulding chambers (28) side by side arranged vertically, so as to bring about the de-aeration of the mix before it enters each moulding chamber (28). The formwork (26) has a vibratory motion imparted to it, so that the vibration acting also on the vertical walls of the moulding chambers effects the compacting of the mix in the chamber (28) itself and the completion of de-aeration, proceeding then to the hardening of the slabs and their removal from the formwork (26). Preferably, the moulding chambers (28) consist of vertical panels (30), mounted side by side in a bundle and having a peripheral shoulder (34) along three sides, while the fourth side, without a shoulder (34), identifies the opening for feeding the mix to the moulding chamber (28). The slabs are obtained with dimensions of more than 3 metres in length by more than 1 metre in width.



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"Method and apparatus for the manufacture of slabs of stone material"

The present invention relates to the manufacture of slabs of stone material and more specifically to an apparatus and a method for the manufacture of slabs of stone material consisting of a natural
5 stone material in granular form and a binder.

The invention further relates to the slabs thus obtained.

Natural stone materials, such as marble, granite, etc. are used in the form of slabs or panels, principally for paving and for wall facing.

10 These materials are extracted in the form of blocks from the quarries and the blocks are subjected to an operating cycle which includes numerous operations, such as, for example, sawing, smoothing, polishing and others.

Natural stone materials have several and undisputed aesthetic and mechanical properties, but their extraction and working are associated with many problems and drawbacks.

15 The first, and not inconsiderable problem is that of the rejects or wastage of the material extracted from the quarries: in general, not more than 20-30% of the material excavated is actually used.

A second problem is that of the sometimes significant differences between one block and another, so that it is not possible to obtain large areas of paving or facing which do not have aesthetic differences or at least differences in colour.

20 A third problem is that of the mechanical resistance to the stresses which these products must undergo both during working and after installation; for this reason, the slabs obtained from the quarry blocks generally have significant thicknesses (of the order of 3 cm and more) so that they are very heavy and not easy to handle.

25 A fourth problem is that of the contained dimensions of the slabs obtained from the quarry blocks which, together with the notable slowness of some basic operations such as sawing (the cutting speed of a sawing frame operating on a block of granite is generally not more than 5 cm/hour), renders the production and installation costs of these products very high, thereby limiting substantially their use on buildings of not inconsiderable commercial value.

30 Efforts have already been made in the past to overcome the main problem, that of utilizing the enormous quantity of waste quarry stone material (that is to say, the aforesaid 70% not used directly) in the production of artificial stone products.

In all the processes tried and carried out, the natural stone material has been ground to a suitable particle size and then mixed with a binder forming a product in the shape of a slab, then carrying out the hardening of the binder.

The first attempt consisted in manufacturing cementitious products or tiles called "terrazzo", consisting of a granulate of natural stone material dispersed in a cementitious matrix.

These products have considerable problems and drawbacks, much so that their production and utilization has substantially ceased.

Indeed, besides having considerable thicknesses and therefore weight for relatively modest sizes (not more than 40 x 40 cm), they have low values of resistance to flexion and abrasion and, moreover, the water absorption is up to 9-10% by weight, therefore increasing the phenomenon of freezing.

A further drawback is that of the appearance which shows the presence of the cementitious binder, so that their use has always been linked to their low cost.

Another process for the manufacture of products in the form of tiles or slabs, designed and carried out on an industrial scale in recent years, provides for the preparation of a mix consisting of a granulate of natural stone material (reduced to a suitable particle size) and of a binder selected among binders of a cementitious nature and those based on a hardenable synthetic resin. The resultant mix is subjected to a first moulding stage, for example by filling suitable dies, so as to form a layer of the desired thickness.

The die is then subjected to a mechanical compacting action (for example by the action of a plate press), maintaining the die under vacuum and at the same time applying a vibratory motion of predetermined frequency.

When this operation, lasting a few minutes, is finished, then the hardening operation begins under conditions which depend exclusively on the nature of the binder.

In the case of a cementitious binder, this operation comprises a first, setting phase, followed by a second, hardening phase, of conventional type in the field of cementitious products, for which the product in slab form is left to rest for the necessary time (of the order of a few days).

However, in the case of a binder consisting of a synthetic resin, such as, for example, a polyester resin, hardening takes place in a very short time, preferably in the presence of a catalyst with the simultaneous application of heat, or at ambient temperature, also adding to the catalyst a promoter.

With analogous technology there are also manufactured products in blocks intended subsequently for sawing into slabs, like the blocks of natural stone material extracted from quarries.

Within the framework of this technology, known generally as the "Bretonstone System" and developed over the years by the applicant of the present application, numerous improvements have been made, directed at improving specific aspects, such as, for example, the production of slabs of large dimensions but of reduced thickness with values of the order of 10 mm or even less, and the provision of reinforcements capable of greatly increasing the bending strength of the slabs and others.

In the specific case of the slab products with cementitious binder, these improvements have made it possible to reduce the water/cement ratio in the binder to the advantage of the reduction of porosity and of the achievement of products having substantially isotropic mechanical properties.

So far, however, it has not been possible to reduce the complexity and bulk of the equipment for manufacturing the slabs, and above all the size of the slabs obtainable has reached limits that cannot be overcome.

Indeed within the framework of the process briefly described above, the moulding phase provides for producing on a temporary support a layer of desired thickness of the starting mix, to be subjected subsequently to mechanical compacting by means of a plate press, simultaneously applying a vibratory motion and maintaining the layer of material under a rather strong vacuum during the compacting phase.

It is clear that the production of slabs of large dimensions raises not inconsiderable problems of industrial equipment.

On the other hand, the production of blocks intended for sawing into slabs is subject, like the blocks extracted from quarries, to a considerable economic problem.

Indeed, when sawing a block of granite, around 25% of the stone material is lost as sawing scrap, so that in the case of artificially produced blocks, further to the losses arising from the scrap the material and to the cost in terms of sawing times, there is also considerable environmental pollution.

A principal aim of the present invention is that of providing a simplified process and installation for the direct production of large size slabs made from a granulate of natural stone material, which may be very thin if desired and maintain the satisfying aesthetic and mechanical qualities of the slabs produced with the conventional method previously summarized.

A further aim of the present invention is that of providing a method and installation of the type indicated above which make it possible to use both a cementitious binder and a binder based on synthetic resin.

These and other aims, that will become clearer in the continuation of the description, are fulfilled by the present invention with which there are produced directly, namely without going through the sawing of a block, slabs of stone material reaching dimensions of up to 3 metres in length or more by widths of more than 1 metre, with thicknesses which, depending on the binder used, may be from 1-3 cm. in the case of cementitious binder, while the thickness may be less than 1 cm in the case of synthetic resin as the binder phase; moreover, the resulting slabs have a bending strength markedly greater than that of the natural stone starting material (for example, in the case of granite, the bending strength of a slab obtained from natural granite varies between 9 and 15 N, while a slab according to the present invention, obtained from granulate of granite bound with cementitious binder has a bending strength between 14 and 18N), a low porosity (which results in a low water absorption and therefore a greater frost resistance), isotropy of the mechanical properties, and a lack of cracks of natural origin typically present in the slabs obtained directly from blocks of natural stone materials.

The method and apparatus according to the present invention are characterized by the following features:

(a) The starting mix, formed from a granulate of natural stone material having a controlled distribution of the particle size, and from the binder, is fed to a metering feed device capable of feeding the mix at a controlled rate of flow to a formwork for moulding the individual slabs, which formwork is in its turn characterized by the presence of a plurality of moulding chambers arranged side by side so that each chamber is in communication through a single upper opening with the outlet or discharge opening of said metering feed device. The formwork is preferably capable of being disassembled so as to allow easy extraction of the hardened slabs from the individual moulding chambers.

(b) Said moulding chambers which, being preferably arranged in a bundle, in effect constitute the formwork, have dimensions corresponding to those of an individual slab arranged vertically, with the major sides (those having dimensions of 3 metres and more) oriented horizontally and obviously the minor sides arranged vertically, and a thickness corresponding to that of the slab to be moulded.

(c) The formwork is associated with means for generating a vibratory motion of predetermined frequency, so that the walls of the individual moulding chambers also have a vibratory motion imparted to them, but is spaced from the outlet or discharge opening of said metering feed device, so that the latter is not connected to said means for generating the vibratory motion and so that said mix, during its travel between said outlet opening and the mouth of each moulding chamber, travels for a short distance in free fall.

(d) Said metering feed device and said formwork are subjected to a vacuum of predetermined value.

Therefore, from the point of view of the process, the present invention provides a process for the manufacture of slabs from a mix which comprises the following operations:

(1) preparation of the starting mix by mixing at atmospheric pressure a granulate of natural stone material and a binder, said granulate having a predetermined particle size range and said binder being selected from a cementitious binder and a hardenable synthetic resin;

(2) filling a feeding and metering tank with a predetermined quantity of mix, uniformly levelled within the tank;

(3) hermetically sealing the charging aperture of the tank;

(4) transfer of said mix at a predetermined rate of flow from the discharge opening of said feeding and metering tank to the mouth of moulding chambers arranged side by side, forming a formwork, said transfer taking place while maintaining both the discharge opening of said tank and the mouth of said moulding chambers under a predetermined vacuum, so that said mix, between said outlet opening and said mouth of said chambers, travels in free fall for a predetermined distance in which said predetermined vacuum takes effect;

(5) application to said formwork of a vibratory motion of predetermined frequency so that the vertical walls of said moulding chambers also have imparted to them said vibratory motion, said vibratory motion being applied during the filling of each moulding chamber to a predetermined degree and continued until the desired compacting of the mix in each chamber is obtained;

(6) transfer of said formwork into a hardening station and

(7) removal of the hardened slabs from the formwork, for the finishing operations.

In its turn, the apparatus according to the present invention, besides the customary station for the mixing of the starting mix at atmospheric pressure and the hardening station, comprises a moulding and compacting station which consists of an upper section for metered feeding of the starting mix and of a lower section in which is located a removable formwork, there being

associated with said lower section means for generating a vibratory motion of predetermined frequency, said formwork consisting of at least one, and preferably a plurality of, moulding chambers closed at the bottom, and having a filling opening located at the upper end in vertical alignment with said upper section, said upper and lower sections being enclosed in a casing
5 associated with means for generating a vacuum inside it and, additionally, a predetermined distance being arranged between the mix discharge opening of said upper section and the mouth of each moulding chamber so that the mix fed in, travels in free fall and under the action of said vacuum for a predetermined distance before entering said mouth of the corresponding moulding chamber, thus effecting the de-aeration of the mix prepared at atmospheric pressure.

10 In the preferred embodiment of the apparatus according to the present invention, said formwork consists of a plurality of moulding chambers which, as already mentioned, define the space for the moulding of a slab "on edge", namely lying vertically with the minor sides perpendicular to the ground and the major sides obviously parallel to the latter. Each moulding chamber is defined by a panel and by the rear surface of the immediately adjacent panel, each panel having peripherally a
15 frame or peripheral support shoulder, preferably having inclined edges to facilitate the removal of the finished slabs, and of a predetermined thickness which defines the width of the moulding chamber and therefore the thickness of the slab which will be moulded therein.

When carrying out the method of the present invention in the apparatus which is also a subject of the invention, the starting mix is prepared by mixing in a conventional atmospheric mixer, which is
20 fed with stone material granulate and binder.

With regard to the former, this is obtained by grinding natural stone material, such as marble, granite, porphyry, etc. with a particle size range, the upper limit thereof is less than the thickness of the slab to be manufactured.

Preferably, the maximum dimension of the particles forming the granulate is no more than a third
25 of the thickness of the final slab and therefore of the moulding chamber.

This particle size range is selected in particular so that the starting mix has the maximum possible fluidity. For example, the particle size range may be determined by applying one of the known formulae, for example the Fuller formula or the Bohlomy formula.

The binder is selected from cementitious binders and those based on hardenable synthetic resin.

30 In the first case, the starting mix is prepared by mixing the granulate with cement, preferably Portland cement with a clinker content of not less than 96%, optionally with the addition of

calcium carbonate having the function, known per se, of preventing the separation of the water of the mix.

In the preferred embodiment, the quantity of cement is of the order of 10-13% by volume or a little more, based on the volume of the starting mix, and the water which is added, substantially equal in volume per cent to that of the cement, provides a ratio by weight between water and cement of the order of 0.30-0.32.

When calcium carbonate is also added (in an amount of approx. 1% by volume based on the final mix), the volumetric ratio between constituents in powder form and water (which constituents in powder form consist of the cement and the calcium carbonate) increases, bringing it above 0.50.

However, in the case of a resinous binder, the granulate is mixed with a liquid resin in such a manner as to moisten all the granules. The resin is preferably selected from polyester, epoxide and acrylic resins.

To the polyester and acrylic resins there is added a hardening catalyst and, depending on the hardening method, optionally other additives such as promoters (in the case where hardening takes place at ambient temperature). However, when the slab to be hardened is heated in the hardening station, the promoter is not necessary and the heat is sufficient to activate the action of the catalyst.

It is important to bear in mind that the starting mix must have a disaggregation, namely a low cohesion, sufficient to allow its de-aeration.

The mix thus prepared must then be fed to the moulding chambers present in the formwork described in detail hereinafter.

For this purpose, according to the present invention, said feeding is carried out in such a manner that the mix is fed at a uniform rate of flow into the discharge section and regulated so that the filling of the moulding chambers takes place gradually, and so that before entering the mouth of each moulding chamber the mix travels for a short distance in free fall from the discharge opening of the metering feed device, so as to facilitate the de-aeration of the mix before it enters the moulding chambers.

For this purpose, said free fall of the mix takes place in an atmosphere maintained under a predetermined and rather strong vacuum.

As the mix penetrates into the moulding chambers, being deposited on the closed bottom of the latter, it is subjected to the action of the vibratory motion applied to the formwork.

Said vibratory motion, which is also transmitted to the vertical walls of the moulding chambers, has a multiple function, namely:

- (a) facilitating the descent of the mix into the chambers and the filling of the latter;
- (b) effecting the tamping of the mix in the moulding chambers and
- 5 (c) promoting the completion of the de-aeration of the mix.

When all the moulding chambers are filled to an equal amount with the tamped and de-aerated mix, the formwork is extracted from the atmosphere under vacuum and transferred to the hardening zone. When hardening is complete (in a time which depends on the nature of the binder) the formwork is disassembled and the slabs positioned on vertical supports.

- 10 More specifically, in the case of a cementitious binder, the actual hardening phase (which is completed in the following 5-6 days), is preferably preceded by the customary setting phase, characteristic of cementitious products, preferably controlling both during setting and during hardening phases the temperature and humidity of the atmosphere in which said phases are carried out.

- 15 However, in the case of a resinous binder, for which the hardening phase has a duration of minutes or a few hours, the operations depend on the nature of the resin and on the catalyzed hardening conditions (with heating or in the presence of a promoter).

Among the advantages of the present invention which will become clearer from the following detailed description, the following are principally worthy of mention:

- 20 (1) The use of waste natural stone material, with significant reduction of the environmental pollution of the quarries,
- (2) The elimination of the dust and the times for sawing the blocks of stone material.
- (3) The obtaining of slabs of very large dimensions, which slabs further have mechanical qualities greater than those of natural stone material.
- 25 (4) The obtaining of slabs having homogenous or isotropic mechanical properties.
- (5) The obtaining of slabs having uniform and constant aesthetic characteristics, free of cracks and natural defects characteristic of natural stone materials.
- (6) The obtaining of very thin slabs, much thinner than slabs of natural stone material, having equal performance and mechanical properties.
- 30 (7) Economy of materials, and in particular of the binder, especially in the case of cementitious binder, with a consequent significant reduction in the manufacturing costs.

Reference will now be made to the appended drawings in order to describe a preferred embodiment of the apparatus of the invention, it being understood that this is provided solely by way of non-limiting example.

In the drawings:

5 Figure 1 is a diagrammatic view in front elevation, partially in section, of the slab moulding station;

Figure 2 is a perspective view of one of the panels forming each moulding chamber; and

Figure 3 is a view in side elevation, partially in section, of an alternative embodiment of the container for metering and feeding the mix to the moulding chambers.

10 Referring to the drawings, and in particular to Figure 1, the slab moulding station of an installation for the manufacture of slabs with the method of the present invention is shown; this installation comprises a preparation station for the starting mix, a slab moulding station (indicated generally by the reference number 10) and finally a hardening zone or station.

15 Since the characteristic and inventive features of the present invention are concentrated in the moulding station 10, for the other two stations, located respectively upstream and downstream of the moulding station, some general indications are sufficient, it being a question of features which are known per se. In particular, in the preparation station for the starting mix there is mounted a mixer operating at atmospheric pressure and equipped with agitators of conventional type. The mixer is fed from above with the ingredients to be mixed, namely granulate of natural stone
20 material, previously provided with the desired particle size distribution, and ingredients of the binder.

Preferably, the preparation of the starting mix takes place discontinuously, or in batches, after which the transfer to the slab moulding station takes place, preferably by means of a metering and feeding tank or container described in detail hereinafter.

25 The slab moulding station comprises a casing or bell 12 which defines a chamber 14 connected to means, not shown, capable of generating inside it a vacuum of predetermined value (preferably of the order of 10-40 mbar of residual pressure).

On the bottom 13 of the casing 12 there is mounted a vibrating structure (indicated as a whole and generally by the reference number 16), comprising a vibrating table or platform 18 mounted
30 resiliently with respect to the bottom 13. By way of example, in the drawing this resilient suspension of the vibrating table is represented by two compression springs 20 mounted between the table 18 and the bottom 13 and calibrated so as to ensure the free vibration of the table 18.

Beneath the vibrating table 18 two compartments 22 are provided, not communicating with the inside of the chamber 14, and in which there are housed two vibrating machines 24 of conventional type (for example of the type with unbalanced rotating masses) that in the embodiment shown are arranged so as to be contra-rotating and therefore to generate a unidirectional vibration (which in the present instance is directed vertically). However, the unidirectional nature of the vibration does not constitute an indispensable condition for the method of the present invention.

The two compartments 22 are isolated from the inside of the chamber 14 for the purpose of preventing the motors of the two machines generating the vibratory motion from being needlessly subjected to the effect of the vacuum, which does not favour the functioning of electric motors in general. Preferably, they are connected by means of an air circulation pipe to the outside air to ventilate and cool the vibrating machines.

Supported on the vibrating table 18 is the formwork indicated generally and as a whole by the reference number 26, and which in the example shown in Figure 1 consists of thirteen moulding chambers 28.

The moulding chambers are formed and bounded by panels 30 of light, non-stick material, such as, for example, polypropylene, so that their handling presents no problem. One of these panels is shown in detail in Figure 2.

Each panel 30 comprises a flat wall 32, the front face 32 of which is framed on three sides by a shoulder 34, which has inclined edges so as to allow the removal of the hardened slabs and has a thickness corresponding to that of the slab to be moulded, and the inner cavity of which has the dimensions of the slab itself.

As can be seen clearly in Figure 1, all the panels 30 are mounted with the identical orientation (namely with the faces 32 and the shoulders 34 all oriented in the same direction) so that each moulding chamber 30 is defined by the face 32 of a panel 30 and by the rear face 36 of the panel immediately opposite, with respect to which the shoulder also acts as a spacer.

All the panels 30 are mounted with the side without a shoulder 34 arranged at the upper end, so as to define the mouth of the moulding chamber 28, through which mouth there is introduced the starting mix mentioned previously in order to fill the chamber itself.

Thus the formwork 26 consists of a bundle of panels 30 held clamped to one another by way of any mechanical device which can be disassembled and reassembled.

In the example illustrated, this device consists of a U-shaped bracket or tie 38 made of metal, provided with two straps or shackles 40 capable of being engaged by a carriage for the introduction and extraction of the formwork 26 with respect to the chamber 14.

For this purpose, on the bottom 13 of the chamber 14 two wheels 42 are provided for the running of the carriage (not shown) capable of engaging the bracket 38 for the extraction of the formwork 26, once the filling of the moulding chambers is completed, and the introduction of a new formwork.

Obviously, for this purpose the casing 12 will be provided with a vacuum sealed door (not shown) and will have a suitable extension in a direction perpendicular to the plane of Figure 1 to allow the movements of introduction and extraction of the formworks.

Above the upper end of the formwork 26 there is positioned on support brackets 45 a device for the metered feeding of starting mix, comprising a container 44 provided with vertical lateral walls 46, having a flared portion 47 at the upper edges, and with a base 48; the base 48 is provided with means, for example with directable blades, for the metered discharge of the mix 50 contained in the container. As can be clearly seen in Figure 1, the support brackets 45, and with them the container 44, do not bear on the formwork, so that the vibratory motion to which the formwork is subjected is in no way transmitted to the container and to the mix 50 contained therein.

Two lipped gaskets 52 prevent the mix from overflowing out of the upper surface of the formwork and therefore of the mouths of the moulding chambers 28.

Corresponding to the position of the container 44, the casing 12 has an aperture 54 for the introduction and extraction of the container, which is uniformly filled with well levelled mix 50, and a sealed lid 56, provided with suitable peripheral gaskets, closes the casing and thus the chamber 14, preventing any communication with the outside.

From Figure 1 it can easily be seen that between the base of the container 44 and the mouth of the moulding chambers 28 a certain space is left, in which the mix is subjected to a free fall and at the same time is subjected to the action of the vacuum to which the chamber 14 is subjected.

As already mentioned, in this way the mix, before entering the moulding chambers, is subjected to an intense de-aerating action which appears decisive for the results which it is desired to obtain, and in particular for ensuring a low porosity and thorough compacting of the mix in the moulding chambers.

To this action there is further added that of the vibration to which the walls of the moulding chambers are subjected, which vibration (as will be seen) on the one hand effects the compacting

of the mix in the moulding chambers and on the other hand, in a known manner, promotes the completion of the de-aeration of the mix.

The method of the present invention, using the apparatus described above, is carried out through the following phases.

- 5 Firstly, there is prepared in air the mix of natural stone material granulate and of binder, continuing the mixing action until the mix is homogenous and fluid.

A container is filled with this mix, taking care that the mix is levelled and distributed uniformly in the container.

The latter is then loaded through the aperture 54 in the casing 12 so as to bear on the brackets 45.

- 10 After having duly hermetically sealed the lid 56, the chamber 14 is connected to the vacuum generating means (for example a vacuum pump) in order to reach the desired degree of vacuum. Simultaneously with the loading of the container 44, a new formwork 26 is placed in the position for filling the moulding chambers.

- 15 At this point the bottom blades of the container 44 are actuated, causing the mix to be discharged in a controlled and therefore metered manner into the mouth of the moulding chambers 28 of the formwork.

The mix, before reaching the mouth of the moulding chambers, travels for a short distance in free fall, where the vacuum prevailing in the chamber 14 takes effect, so that it is subjected to a de-aerating action.

- 20 It is important to control the discharge flow rate of the mix through the bottom of the container 44, so that the quantity of mix which penetrates into each chamber cannot clog the mouth of the latter but drops to the bottom.

- 25 The vibratory motion set up in the meantime facilitates the descent of the mix to the bottom of each moulding chamber and the completion of the de-aeration of the mix itself before the arrival of more mix discharged from the container 44, and brings about perfect tamping of the mix within each chamber.

When all the moulding chambers have been filled as far as their mouth, the formwork is removed from the chamber 14 and it is replaced with a new formwork.

- 30 The same occurs with regard to the container 44 for the metered feeding of fresh mix, in which case it is possible to shorten the idle times by providing more than one container, so as to allow them to be filled with fresh mix in the mixing station while the moulding chambers are filled with mix contained in the container positioned in the chamber 14.

The formwork with the moulding chambers filled with tamped mix is transferred to the hardening station, where it is disassembled after the slabs moulded in the chambers have reached at least the minimum consistency for handling.

In the case of cementitious binder, this means that the disassembly of the formwork takes place only after the primary hardening phase is completed (of the order of 24 hours).

It is worth noting that the panels 30 of the bundle forming the formwork are preferably made of non-stick plastics material, such as, for example, polypropylene, so that the separation of the slabs from the panels themselves does not entail any difficulty and/or damage to the raw slabs.

The slabs thus obtained, as already mentioned, have lengths which may be more than 3 metres by a width which may reach more than one metre, with the obvious economic and constructional advantages.

In the alternative embodiment of the container 44 illustrated in Figure 3, in which identical numbers represent the same parts of the container shown in Figure 1, the difference relates to the base 58 which consists of a plurality of parallel rods 60 between which are placed half-cylinders 62, rotatable in a controlled manner between the closure position, shown in Figure 2, and the opening position in which the half-cylinders 62 are rotated through 90°, thus allowing the passage of the mix at a controlled and metered rate of flow.

As discussed before, the starting mix is of decisive importance for the properties of the slabs obtained.

In the case of slabs with cementitious binder, the formulations as a rule comprise from 10.50 to 12.50% by volume of cement and around 10.50% by volume of water, the remainder consisting of the inert stone granulate. In this way, the ratio by weight between water and cement is between 0.31 and 0.29.

Preferably, the starting mix also contains a fluidizer of known type for cementitious pastes and, as already mentioned, it is possible to add to the mix calcium carbonate up to 1% in volume, so as to reduce the level of the water/cement ratio.

With regard to the aggregates in the form of granulate, some illustrative and non-limiting examples will now be provided (based on 1 cubic metre of starting mix):

A. Granite and marble slabs with aggregates up to 6-8 mm.

Cement	10.50% by volume (equal to approx. 330 kg)
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Water	10.50% by volume (equal to approx. 105 kg)
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aggregates (volume appr. 79%) (i) granite approx. 2067 kg

(ii) marble approx. 2106 kg

particle size distribution (mm): 0.1 - 0.3

0.3 - 0.7

0.7 - 1.2

5 1.2 - 2.5

2.5 - 4.0

4.0 - 6.0

6.0 - 8.0

The above percentages are derived from the application of the Bohlomy formula.

10 B. Marble and granite slabs with finer aggregates

Cement 12.7% by volume (equal to approx. 400 kg)

calcium carbonate 0.8-1% by volume (equal to approx. 25 kg)

water 12.4% by volume (equal to approx. 124 kg)

aggregates (volume appr. 74%) (i) granite approx. 1924 kg

15 (ii) marble approx. 1998 kg

particle size distribution (mm): 0.1 - 0.3

0.3 - 0.7

0.7 - 1.2

1.2 - 2.5

20 2.5 - 4.0

Also provided for are formulations with aggregates consisting of quartz sands or silicas having a particle size up to 6 mm, for which preference is given to binders based on hardenable synthetic resins.

25 From the preceding description it will be seen that it makes it possible to manufacture slabs of dimensions substantially greater than those possible up to now with the prior art, using stone materials hitherto rejected and without losses due to sawing dust.

Furthermore, the elimination of the sawing phase makes it possible to shorten to a more than significant degree the production times for the slabs.

30 Finally, differing from what has been known up to now, the same apparatus can be employed for the use of both cementitious binder and synthetic resin binder.

According to a particular embodiment of the present invention, the filling of the moulding chambers is carried out to a level slightly above their mouth, so that the slabs at their upper end

(in relation to the formwork), until the end of the hardening, remain joined to one another (with a comb arrangement) to be separated then individually in the finishing phase.

Finally, it is to be understood that conceptually and mechanically equivalent variations are possible in the apparatus of the invention.

Claims

1. A method for the manufacture of slabs of stone material comprising the following operations:

(1) preparation of the starting mix by mixing under atmospheric pressure a granulate of natural stone material and a binder, said granulate having a predetermined particle size range and said binder being selected from a cementitious binder and a hardenable synthetic resin;

(2) filling of a feeding and metering tank with a predetermined quantity of mix, uniformly levelled within the tank;

(3) hermetic sealing of the charging aperture of the tank;

(4) transfer of said mix at a predetermined rate of flow from the discharge opening of said feeding and metering tank to the mouth of moulding chambers arranged side by side, forming a formwork, said transfer taking place while maintaining both the discharge opening of said tank and the mouth of said moulding chambers under a predetermined vacuum, so that said mix, between said outlet opening and said mouth of said chambers, travels in free fall for a predetermined distance in which said predetermined vacuum takes effect;

(5) application to said formwork of a vibratory motion of predetermined frequency so that the vertical walls of said moulding chambers also have imparted to them said vibratory motion, said vibratory motion being applied during the filling of each moulding chamber to a predetermined degree and continued until the desired compacting of the mix in each chamber is obtained;

(6) transfer of said formwork into a hardening station and

(7) removal of the hardened slabs from the formwork for the finishing operations.

2. A method for the manufacture of slabs of stone material according to claim 1, characterized in that the granulate of natural stone material is selected to have a particle size range such that the maximum dimension of the particles is less than the thickness of the slab to be manufactured.

3. A method for the manufacture of slabs of stone material according to claim 2, characterized in that said maximum dimension of the particles is less than once 1/3 of the thickness of the slab to be manufactured.

4. A method for the manufacture of slabs of stone material according to claim 2, characterized in that said particle size range is selected so that the starting mix has a disaggregation such as to allow its de-aeration in said phase of free fall and under the action of said vacuum.

5. A method for the manufacture of slabs of stone material according to claim 1, characterized in that in the case of cementitious binder the quantity of cement is of the order of 10-13% by volume

based on the volume of the mix, and the mix water is in an amount substantially equal in volume per cent to that of the cement, in order to provide a ratio by weight between water and cement of the order of 0.30-0.32.

6. A method for the manufacture of slabs of stone material according to claim 5, characterized in that the starting mix also has added to it calcium carbonate so as to increase the volumetric ratio between constituents in power form (cement and calcium carbonate) and water to more than 0.50.

7. A method for the manufacture of slabs of stone material according to claim 6, characterized in that said calcium carbonate is added in an amount of approx. 1% by volume based on the final volume of mix.

8. A method for the manufacture of slabs of stone material according to claim 1, characterized in that in the case of resinous binder the latter is selected from polyester resins, epoxide resins and acrylic resins that are hardenable by means of heat and/or by catalytic action.

9. A method for the manufacture of slabs of stone material according to claim 8, characterized in that in the case of polyester and acrylic resins, there is added to the starting mix a hardening catalyst and optionally a promoter for the catalyst, when hardening is not carried out by means of heat.

10. A method for the manufacture of slabs of stone material according to claim 1, characterized in that said vacuum applied during the filling of said moulding chambers is of the order of 10-40 mbar of residual pressure.

11. An apparatus for the manufacture of slabs of stone material starting from a mix consisting of a granulate of stone material and of a binder, comprising a station for mixing said starting mix at atmospheric pressure, a slab moulding and compacting station and a hardening zone or station, characterized in that said moulding and compacting station consists of an upper section for metered feeding of the starting mix and of a lower section in which is located a removable formwork, there being associated with said lower section means for generating a vibratory motion of predetermined frequency, said formwork consisting of at least one moulding chamber with closed bottom and having a filling opening located at the upper end in vertical alignment with said upper section, said upper and lower sections being enclosed in a casing associated with means for generating a vacuum inside it, and a predetermined distance being further arranged between the mix discharge opening of said upper section and the mouth of said at least one moulding chamber so that the mix being fed in travels in free fall and under the action of said vacuum for a

predetermined distance before entering said mouth of the corresponding moulding chamber, thus effecting the de-aeration of the mix prepared under atmospheric pressure.

12. An apparatus for the manufacture of slabs of stone material according to claim 11, characterized in that it comprises a plurality of moulding chambers constituting said formwork, each chamber defining a space for moulding a slab lying vertically or "on edge".

13. An apparatus for the manufacture of slabs of stone material according to claim 12, characterized in that said moulding chambers are formed and bounded by a plurality of panels, each comprising a flat wall having a face framed on three sides by a shoulder having a thickness corresponding to that of the slab to be moulded, so that the cavity defined by said shoulder has the dimensions of the slab to be manufactured, said panels being mounted to form said formwork with identical orientation, namely with the faces provided with said shoulder oriented all in the same direction and in contact with the flat face of the immediately adjacent panel, all said panels being mounted with the side without said shoulder arranged at the upper end so as to define the filling opening of the moulding chamber through which is introduced the mix issuing from said upper section, said panels being clamped into a bundle by means of a mechanical device that can be disassembled and reassembled.

14. An apparatus for the manufacture of slabs of stone material according to claim 13, characterized in that each panel is of light, non-stick material, in particular polypropylene.

15. An apparatus for the manufacture of slabs of stone material according to claim 13, characterized in that said shoulder framing the three sides of each panel has inclined edges to facilitate the removal of the hardened slabs.

16. An apparatus for the manufacture of slabs of stone material according to claim 13, characterized in that said mechanical device for clamping said panels consists of a U-shaped metal bracket provided with two straps that can be engaged by a carriage for the movement of the formwork.

17. An apparatus for the manufacture of slabs of stone material according to claim 12, characterized in that said upper and lower sections are housed in a casing or bell which defines a chamber connected to means for generating a predetermined vacuum, and on the bottom of said casing is mounted a vibrating structure comprising a vibrating table or platform mounted resiliently with respect to the bottom of the bell, there being associated with said table or platform means for generating a vibratory motion of predetermined and controllable frequency, said formwork being supported on said vibrating table or platform.

18. An apparatus for the manufacture of slabs of stone material according to claim 17, characterized in that said means for generating the vibratory motion are housed in compartments provided below said vibrating table.

19. An apparatus for the manufacture of slabs of stone material according to claim 18,
5 characterized in that said means for generating the vibratory motion are two vibrating machines of the type with unbalanced rotating masses arranged so as to be contra-rotating in order to generate a unidirectional vibration directed vertically.

20. An apparatus for the manufacture of slabs of stone material according to claim 18,
10 characterized in that said compartments housing the vibrating machines are in communication with atmospheric air for ventilation and cooling.

21. An apparatus for the manufacture of slabs of stone material according to claim 17,
characterized in that said upper section consists of a device for the metered feeding of mix comprising a container provided with vertical lateral walls, having a flared portion at the top, and
15 of a base provided with means for the metered discharge of the mix contained in the container, said container being devoid of contact with said formwork so that it does not receive any vibratory motion.

22. An apparatus for the manufacture of slabs of stone material according to claim 21,
characterized in that the base of said container is equipped with lipped gaskets projecting
20 downwards so as to delimit the area of free discharge of said mix towards the mouths of said moulding chambers of said formwork.

23. An apparatus for the manufacture of slabs of stone material according to claim 21,
characterized in that said container can be extracted from said section for uniform, levelled filling
with mix taken from the preparation station for the starting mix.

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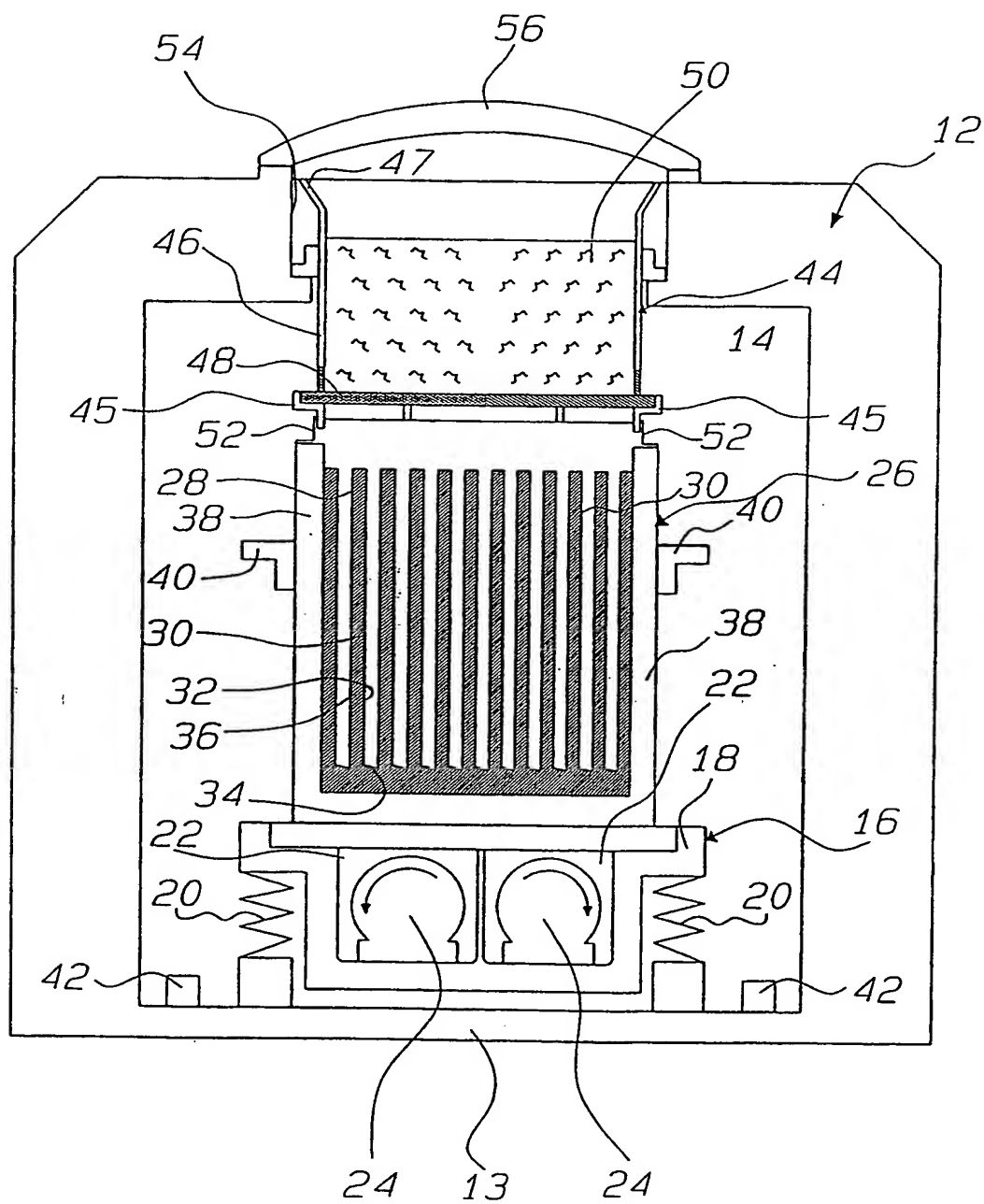


fig. 1

2/2

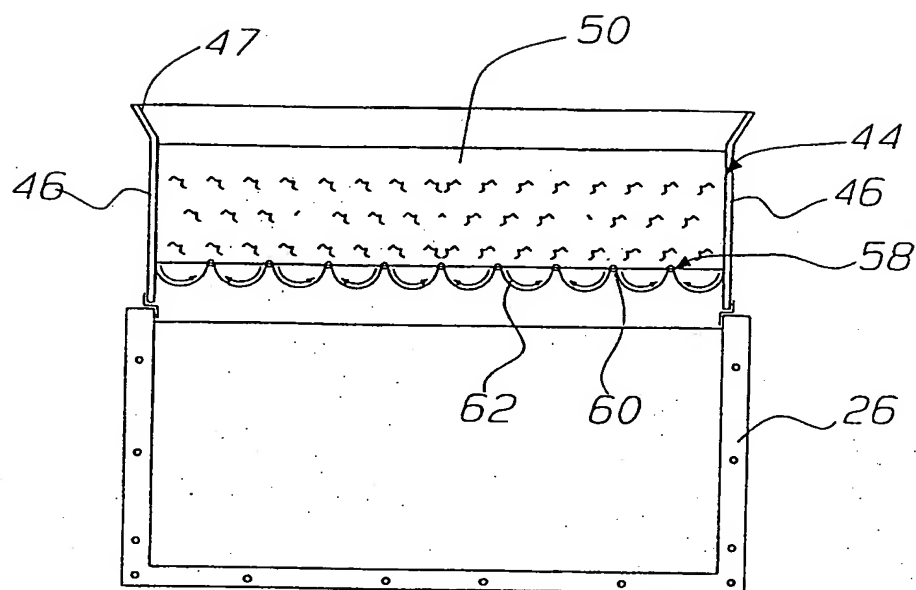


fig. 2

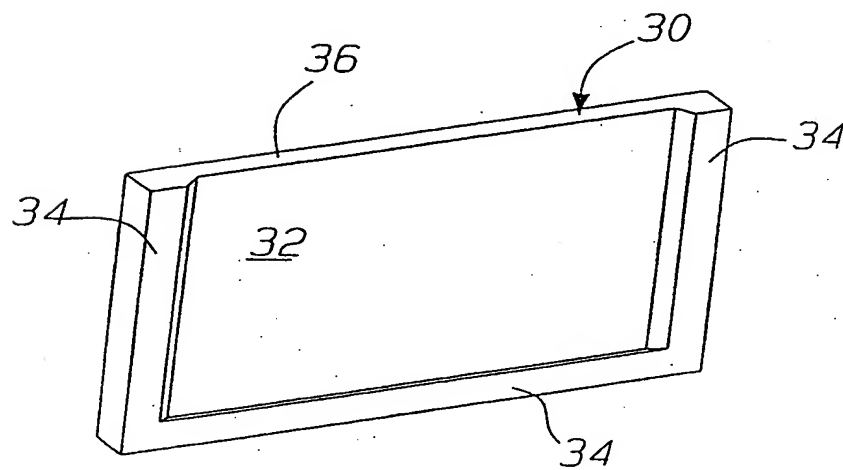


fig. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/00400

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C67/24 B28B7/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C B28B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	GB 695 327 A (THOS. C. FAWCETT LTD.) 5 August 1953 (1953-08-05) page 1, line 66 -page 1, line 84 page 4, line 15 -page 4, line 32 figures 9-12	1,11
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 224 (C-599), 24 May 1989 (1989-05-24) & JP 01 037449 A (SONY CORP), 8 February 1989 (1989-02-08) abstract	1,11,17, 19,20
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Int. Application No

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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